E7.4-10.0.3.2
CR-135873

Interim Report

ORSER-SSEL Technical Report 25-73

AGRICULTURAL LAND USE MAPPING

A. D. Wilson and G. W. Petersen

(E74-10032) AGRICULTURAL LAND USE
MAPPING Interim Report (Pennsylvania
State Univ.) 26 p HC $3.50 CSCL 08B

N74-12121

Unclas
G3/13 00032

ERTS Investigation 082
Contract Number NAS 5-23133

INTERDISCIPLINARY APPLICATION AND INTERPRETATION OF ERTS DATA
WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

Office for Remote Sensing of Earth Resources (ORSER)
Space Science and Engineering Laboratory (SSEL)
Room 219 Electrical Engineering West
The Pennsylvania State University
University Park, Pennsylvania 16802

Principal Investigators:

Dr. George J. McMurtry
Dr. Gary W. Petersen

Date: May 1973

AGRICULTURAL LAND USE MAPPING

A. D. Wilson and G. W. Petersen

Three diverse agricultural sites were chosen with the intent of developing an approach to agricultural land use mapping from ERTS-1 data. Spectral, spatial, and temporal factors are being used to map land use and to delineate soil associations. The relative usefulness of photointerpretation, image enhancement, and computer analysis in this effort are being explored. Ground truth, in the form of underflight photography and multispectral scanner (MSS) data; results from ground-based projects conducted by Federal, State, and University personnel; and actual visits to the test sites; are being used in conjunction with ERTS-1 data analysis.

Site Selection

The three sites selected for analysis include one each in Pennsylvania, Texas, and Montana. Difficulties encountered in an initial study of the Lancaster County area, in Pennsylvania, led to study of the sites in Montana and Texas, where agricultural features are larger and more uniform than those found in Pennsylvania. The extensive ground truth data available for these two sites, including on-site familiarity with the areas on the part of one of the investigators (Wilson), was an added factor in their selection. The three sites, taken together, represent a broad range of soils, soil parent materials, climate, modes of agricultural operation, crops, and field sizes.

Ground Truth Sources

USGS 7 1/2 minute quadrangle maps (1:24,000) are being used to locate and identify cultural features, drainage areas, and other geographic landmarks for all three sites. Geologic maps are consulted for information concerning possible subsurface features and bedrock bodies which may have surface expression or influence overlying soils. County soil survey maps, prepared on a base of aerial photography, provide ground truth for soil classifications. Ground truth sources specific for each site are discussed in the section dealing with that site.

Methodology

The method of procedure for each of the three areas under study has been as follows:

1. Locate the specific area on ERTS-1 images and computer tapes; subset the area onto a working tape. Locate the area on available underflight photography; investigate other ground truth sources.

2. Use the NMAP and UMAP programs[1] to further specify the area and locate immediately identifiable features. Compare the computer output to the ERTS image and to high-altitude aircraft photography, when available.

3. Use statistical and classifying programs to further identify and classify vegetation types, crop species, soil associations, and cultural features on the computer-generated thematic maps. Relate these to the available ground truth information, including high and low altitude aerial photography.

4. Continue analysis until a satisfactory map has been obtained.

The data analysis methods evolved in the study of the three sites will be compared with those developed by the General Electric Corporation, using their data analyzer, "Image 100." This machine presents ERTS-1 data on a color cathode ray tube. Training areas can be selected and manipulated visually in the discrimination of land use classes. A hard copy of the results displayed on the cathode ray tube can be obtained at any point in the process.

---

[1]Detailed program descriptions may be found in ORSER-SSEL Technical Report 10-73.

Lancaster County, Pennsylvania

An area approximately 300,000 acres in size was selected for analysis within Lancaster County, in southeastern Pennsylvania. This county, noted for its quality agricultural production, is the center of the Pennsylvania Dutch country. Field size is generally small (4 to 10 acres) with major crops of corn, hay, small grains, and tobacco. The economy of the area revolves around livestock, with much of the crop production being used for feed. The soils are residual, derived largely from limestone, shales, and sandstones. The climate is humid; rainfall in excess of 40 inches per year is evenly distributed throughout the growing season. The landscape is bisected by many small streams. The topography is characterized by broad valleys separated by ridges of sandstone and shale. Native vegetation is of mixed oak, or oak and hickory.

The test site is covered by low altitude photography (5 to 15 thousand feet) on a seasonal basis, and by high altitude photography (65,000 ft) on a periodic basis. In addition to the study of data from these flights (predominantly by C130 and U2 aircraft), maps and county reports have been consulted for topographic, geologic, and soil information and field data are collected on visits to the area in conjunction with ERTS-1 overpasses.

Procedure

This site was the first of the three sites selected for a study of agricultural land use. The first clear ERTS-1 scene available of the area, therefore, was selected for study, even though optimum conditions for the study of agricultural land use do not exist in the fall, with most of the crops harvested and crop residues littering many of the fields. The scene was that of October 11, 1973 (1080-15185). Approximately one inch of rain was recorded three days prior to this ERTS-1 pass, and the first frost of fall occurred the night before.

A channel 7 positive transparency were overlaid on a map at the scale of 1:1,000,000 to locate the towns of Lancaster, Denver, Blue Ball, and Lititz. Highway networks, urban areas, and vegetative patterns were delineated on overlays on these transparancies. Possible target areas were selected for computer analysis. A subset of the test area was made from the NASA tape onto an ORSER working tape. Computer-generated brightness maps, using the NMAP program, were visually related to the transparencies by pattern association. This was done for individual channels, as well as for all four channels combined. Remote sensing units seen on the brightness map were related to geographic features shown on topographic maps at the 1:24,000 scale. A 35 mm slide of the geology of the area[1] was projected onto the digital brightness maps to identify features which might have geologic significance. Sandstone ridges, limestone valleys, drainage patterns, and some cultural features were determined from the brightness map. Bright areas were associated with bare fields and quarries, and a dull area was identified as a swamp.

A uniformity map, using the UMAP program, was output, and compared to the brightness map. From these two maps, training areas were selected for analysis by the STATS program. This program develops a variety of basic statistical values and determines signatures from selected training areas. These statistics are used in supervised classifiers such as the DCLASS program. Results of using these signatures with the DCLASS program, however, were inconclusive for the Lancaster area because the map patterns could not be recognized.

The problems encountered with the supervised classification, led to the use of the unsupervised classifier, DCLUS. This classifier randomly selects up to 900 points and forms up to 10 separable categories with a minimum critical euclidean distance between categories chosen by the user. A minimum distance of 2.0 was chosen in this case. Output is in the form of a map of the area, a table of spectral signatures of the categories, and a table of the euclidean distances between the categories. Five widely separated categories were delineated by this method. The first two were related to forested sandstone ridges. These areas agreed very closely with vegetated areas indicated on the USGS topographic maps. The third category corresponded closely to bodies of water, such as

[1]This slide was made from the 1960 edition of the Geologic Map of Pennsylvania, put out by the Pennsylvania Topographic and Geologic Survey.

swamps, farm ponds, and streams. The last two categories occurred in cultivated areas. One of these categories had a high response in channels 5 and 6, and was tenatively identified as mapping areas of bare soil. Areas which did not fall into any of these categories were not mapped.

The DCLUS program was then used in small areas to subclassify some of these five categories, and to establish signatures for some areas which had not yet been mapped. The resulting map is shown in Figure 1 . (The category specifications and symbols for this map are shown on Table 1 .) By this method, the water signature was further subdivided into four categories: CLEAN WATER, two categories of DIRTY WATER, and VEGETATED WATER. Many additional categories were established within the forested and cultivated areas, but they presented a pattern too complex for clear identification from the ground truth available at the time of this analysis. Using the town of Denver, which did not register on the output, (and does not lie within the area shown on the figure), an attempt was made to develop a signature for small communities. This was only partially successful, probably due to the fact that a large percentage of Denver is vegetated. Individual fields could not be mapped. This was partially because of their small size (usually less than five acres) and partially because of the wide variety of agricultural practices, including contour plowing. Aircraft data were an invaluable aid in the analysis of the DCLUS output. It was from these photographs that the true complexity of the land use patterns of Lancaster County became evident and the problems of mapping these from ERTS-1 data were clarified.

Results and Conclusions

The use of ERTS-1 digital data for the automatic mapping of land use categories appears feasible. Forest land, cultivated land, and water were classified within 25,000 acres in an area of very complex land use patterns. Additional classifications made within these categories are being identified from ground truth as it becomes available. Four water classifications have been identified and verified.

Because of the complexity of the land use patterns in the Lancaster County area, it was deemed wise to turn attention to the two western

Figure 1: Classification map for the Lancaster County area. (Symbols are defined on Table 1 .)

Table 1 : Category Specifications and Symbols for the Lancaster Area Map

Category Name	Number	Symbol	Channels: 1	2	3	4
			Specifications			
QUARRY	1	Q	40.75	36.25	30.25	11.50
FOREST	2	:	20.80	13.30	26.85	15.40
FOREST	3	:	18.36	10.43	23.00	13.36
QUARRY	4	Q	47.86	49.29	45.29	18.57
UNKNOWN	5	/	45.25	41.25	49.19	25.25
CULTIVATED FIELDS	6	+	34.14	35.57	40.24	19.95
CULTIVATED FIELDS	7	+	32.78	30.00	38.63	20.00
SUNNY FOREST	8	@	23.40	16.07	38.33	23.53
CLEAN WATER	9	1	20.15	12.86	9.37	2.33
DIRTY WATER	10	2	21.00	14.67	10.00	3.33
DIRTY WATER	11	3	21.60	16.20	15.80	7.20
VEGETATED WATER	12	4	21.00	14.25	17.75	7.50
QUARRY	13	Q	41.13	38.67	33.27	13.43
QUARRY	14	Q	39.00	33.83	28.00	11.00
QUARRY	15	Q	42.58	40.33	36.48	15.08
ROCK OUTCROP	16	B	43.88	38.46	52.50	27.60
PASTURE	17	-	25.50	21.08	31.53	17.57
PASTURE	18	-	25.22	21.77	27.02	14.11
CULTIVATED FIELDS	19	+	27.60	25.77	30.72	15.76
PASTURE	20	-	22.82	17.25	27.49	15.54
SUNNY FOREST	21	@	20.13	12.40	32.98	21.17
CULTIVATED FIELDS	22	+	32.20	33.16	36.19	17.46
CULTIVATED FIELDS	23	+	28.62	25.68	35.83	18.92
CULTIVATED FIELDS	24	+	29.73	29.34	32.46	16.31
SUNNY FOREST	25	@	22.73	15.11	32.61	19.50
SUNNY FOREST	26	@	20.61	13.11	36.52	23.42
BARE SOIL	27	*	37.00	42.42	43.33	20.25
BARE SOIL	28	*	39.71	46.86	45.43	21.43
CULTIVATED FIELDS	29	+	27.50	24.17	37.33	20.17

agricultural areas before continuing with the Lancaster study. Experience gained from study of these areas of larger fields and farms would most likely be of considerable assistance in later study of Lancaster County, after data from the summer of 1973 becomes available.

Hill County, Montana

The Hill County, Montana, site is located in the Hard Winter Wheat Belt of the Northern Great Plains. The climate is semi-desert to arid, with up to 15 inches of rainfall occurring mostly in the winter and spring. Soils are developed in glacial till; the topography is flat to gently rolling; an occasional stream bed traverses the terrain. In areas of lesser rainfall, large sections have been left in native short grass vegetation, used as rangeland for cattle. The temperature has a large daily fluctuation as well as a large seasonal variation.

The region is entirely agricultural, with major crops of winter wheat, spring wheat, and barley, in two-year rotation with summer fallow. Farm size varies from 1500 to 5000 acres, with individual fields ranging from 40 to 100 acres in size. Fields are usually either 1/2 to 1 mile long, with widths from less than 2178 feet (80.5m) to one-quarter mile (402.3m). The land is surveyed on the township and range system. Most fields are rectangular in shape and oriented north-south, to control wind erosion. However, the government programs on acreage production allotments confuse the pattern, forcing farmers to plant less than full fields to satisfy their acreage requirements.

Two test sites were selected. The location of these is shown in Figure 2. The principal site is the Kenneth E. Wilson farm near Kremlin, Montana. The primary investigator is personally acquainted with this site and the surrounding fields. A secondary test site is located approximately 20 miles northeast of the primary site. The Agricultural Stabilization and Conservation Service (ASCS) has collected ground truth for this area for each pass of ERTS-1 since launch. These data are in the form of records of crop, stage of growth, and condition, for each field. Species identification and acreage measurements have been supplied by the U. S.

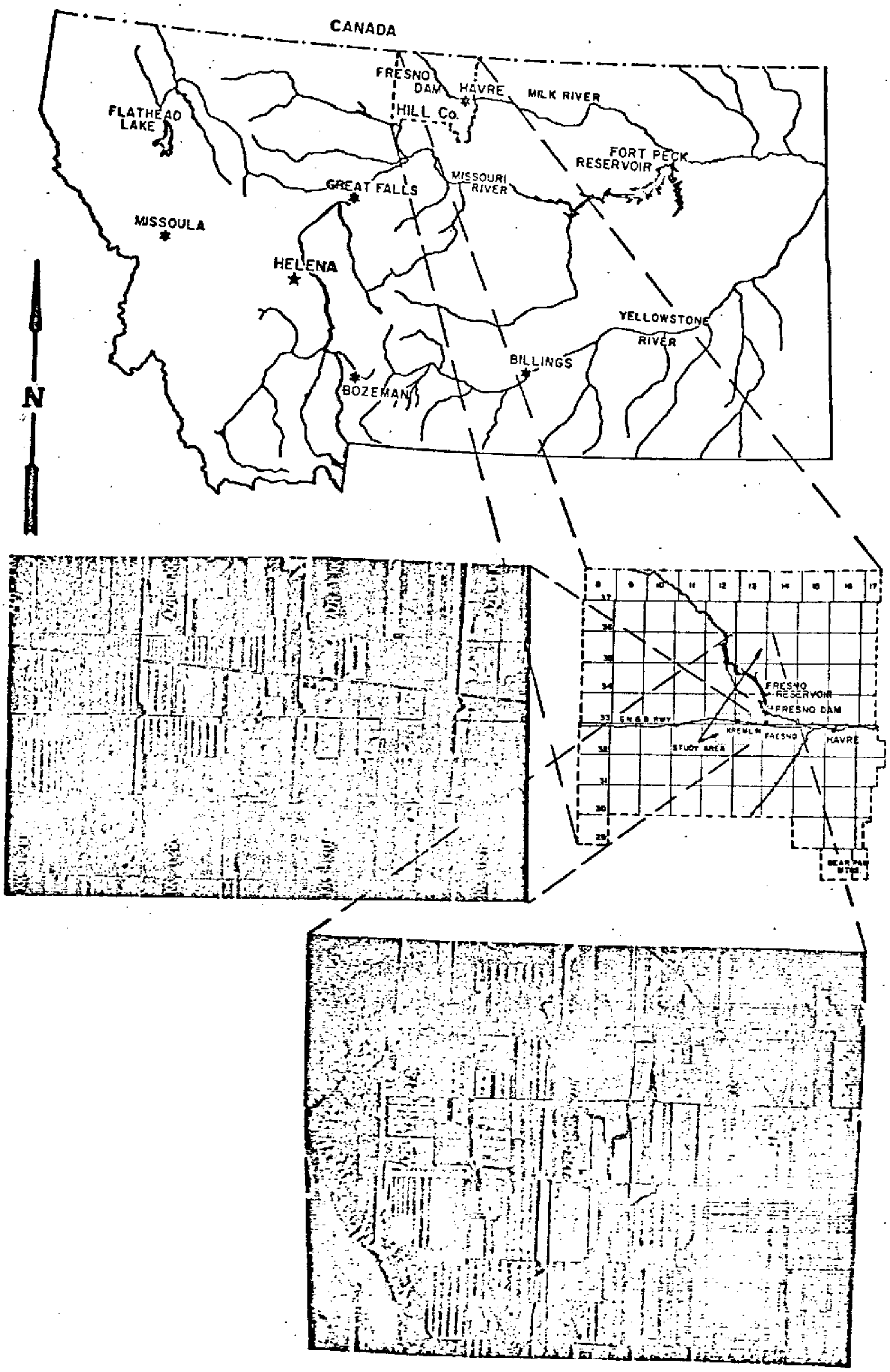

Figure 2: Location of the two test sites in Hill County, Montana.

Department of Agriculture (USDA) Crop Reporting Service. The U. S. Geological Survey (USGS) has recently flown this area of Montana as part of their program to up-date the topographic maps of the United States. These photographs are available at various scales and have been used in conjunction with field ground truth. USGS topographic maps at a scale of 1:250,000 were used to locate specific field boundaries. A U. S. Bureau of Soils 1920 Reconnaissance Soil Survey Map, and a USGS 1955 Geological Map of Montana, both at a scale of 1:500,000 were also available for use. For the primary test site, the ASCS Crop Planting Plan was used, and a photomosaic of the area, put out by the USDA in 1969 at a scale of 1:63,360, was extremely useful. Weather data for the first two weeks in September 1972 are presented in Table 2.

Procedure

The objective of this study was to produce a thematic map of the area depecting the following categories: stubble, fallow, native grassland, planted pasture, farmsteads, roads, railroads and water bodies.

Table 2: Weather Data for Hill County, Montana, the First Two Weeks in September, 1972

Date	Temperature Maximum	Temperature Minimum	Precipitation
9/1/72	88	41	None
9/2/72	96	47	None
9/3/72	82	47	Trace
9/4/72	72	46	None
9/5/72	70	49	None
9/6/72	75	41	None
9/7/72	83	35	None
9/8/72	90	41	None
9/9/72	91	54	None
9/10/72	87	50	None
9/11/72	92	48	None
9/12/72	91	52	None
9/13/72	89	62	None

ERTS-1 scene 1052-17452, from September 13, 1972, was selected. The primary test site lies approximately between lines 1300 and 1400 and elements 1850 and 2200; the secondary test site is located within lines 1098 and 1160 and elements 2035 and 2222. (These test sites are shown on photomosaics in Figures 3 and 4.) A slight banding of data in channels 4, 5, and 6 appears as a lowering of response values by approximately 2 percent. This banding is not consistent through the scene.

A previously prepared template was used as a guide to select lines and elements of an area to subset. The SUBSET program[1] was used to convert data from the NASA to the ORSER format and to subset the data onto a working tape. A small block of the area was run with the NMAP program to set the class intervals for a complete run of the tape by NMAP. The large (8 by 8 ft) brightness map was used to locate the specific block that included the desired test sites. Several runs were made with different groupings of brightness percentage classes until a map was produced that appeared to best represent the expected field pattern.

Uniformity maps were produced using the UMAP program and several class intervals. This program compares nearest neighbors. If the percentage difference between the adjacent RSU's (remote sensing units) is less than a user-chosen class group, the program assigns the appropriate mapping symbol to that RSU. For this data, the class including all RSU's with less than 5 percent brightness difference between adjacent RSU's tended to produce large areas of uniformity. These patterns were larger than the expected field pattern. When the class was reduced to 4 percent the areas of uniformity were less than full fields. It was decided to use the 4 percent uniformity groups for selection of spectral signature training sites. These areas of uniform brightness were input to the STATS program. It was necessary to select some areas outside the specific test sites as neither site contained large enough areas of uniform brightness for statistically valid sampling. The initial training areas for signature determination were based on brightness, rather than a mapping

[1]For complete program descriptions see ORSER-SSEL Technical Report 10-73.

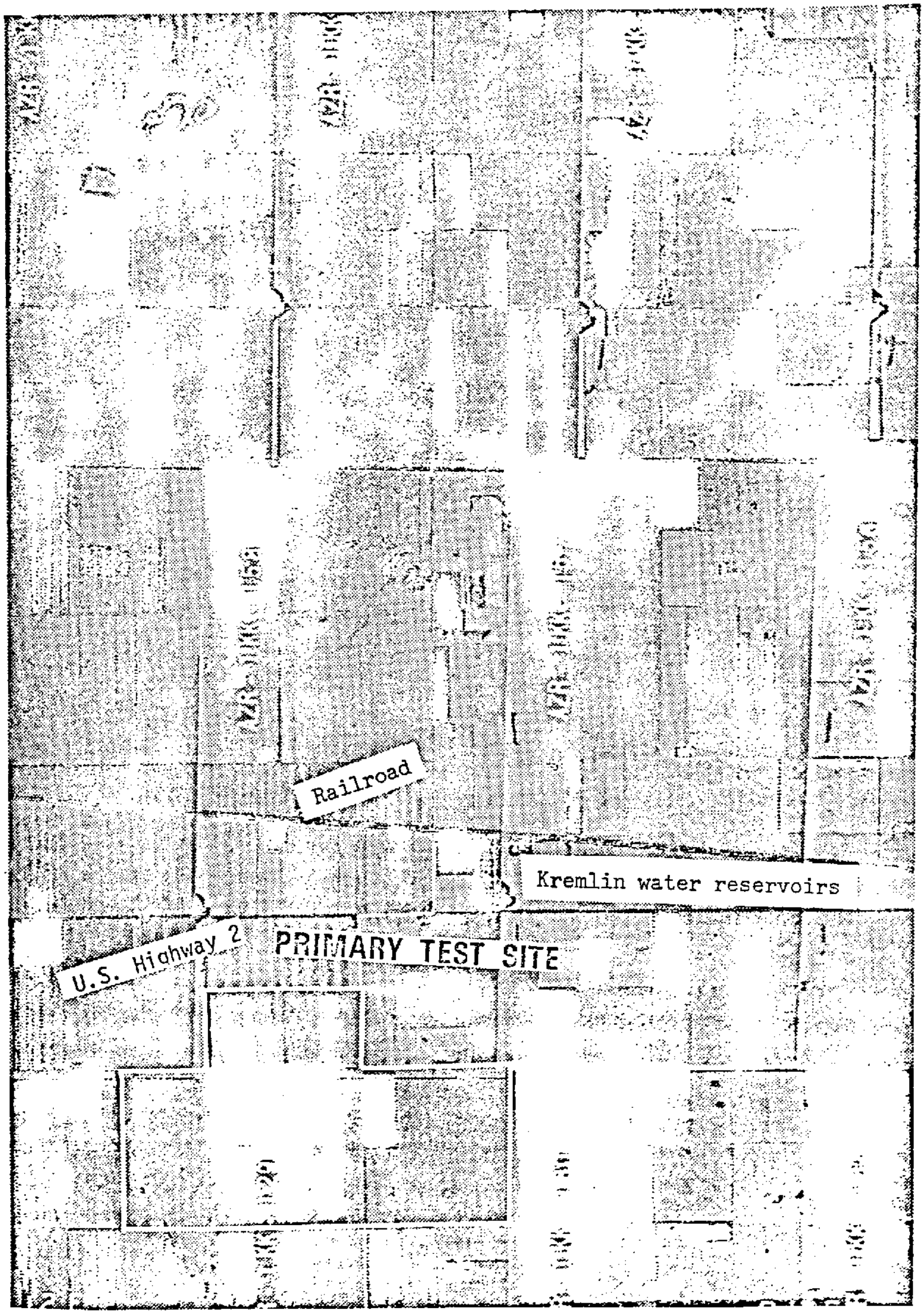

Figure 3: Primary test site shown on the 1969 USDA photomosaic, at a scale of 1:63,360.

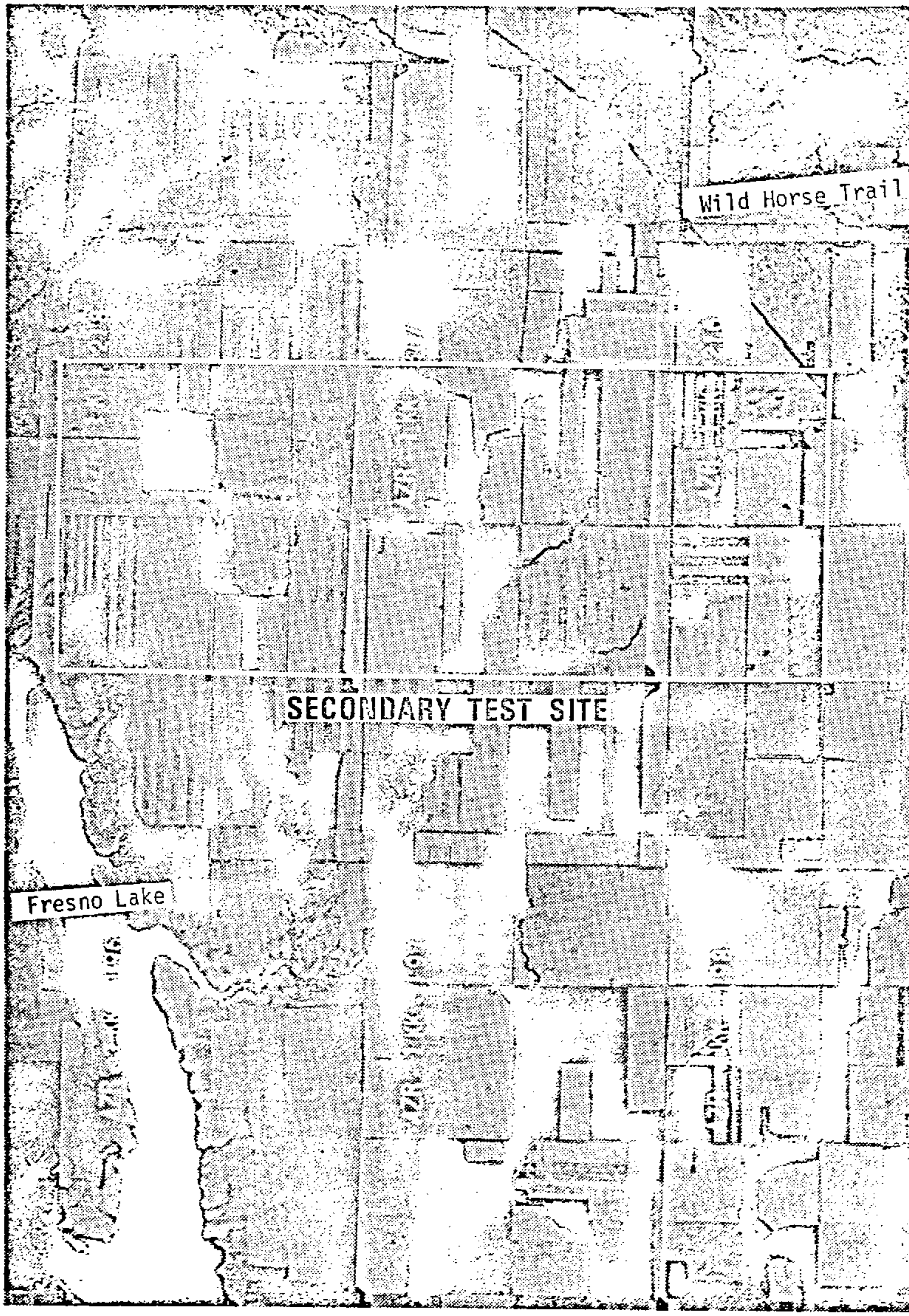

Figure 4: Secondary test site shown on the 1969 USDA photomosaic, at a scale of 1:63,360.

category, such as stubble or summer fallow. This was necessary because it is very difficult at this stage to precisely identify a character in the computer output with respect into its corresponding ground location. A preliminary signature classification is frequently of considerable aid in relating computer output to surface features.

The signatures obtained from STATS were then input to the DCLUS program. At this stage there were two locators. Near the primary test site, a linear trace was either the main track of the Great Northern and Burlington Railroad or U.S. Highway 2, which parallels the railroad. Fresno Dam, near the secondary test site, was readily apparent. The location of the community of Kremlin, with its water storage ponds, was not clear. In order to more precisely locate this town, a grid was constructed which could be placed over the computer output to measure distances from a known locator, such as Fresno Dam. This grid was laid out north-south, hence not parallel to the ERTS-1 orbit, by adjusting the pixel size by the cosine of the azmuth. The pixel size, 57.55 meters across the elements and 79.3 meters down the lines, was then scaled to the computer output. When this grid was laid over the DCLASS map, it was found that the blank area thought to be Kremlin was actually a deserted homestead, 1.5 miles east of Kremlin.

An area just large enough to encompass the community of Kremlin, now precisely located, was then selected for analysis with the unsupervised classifier, DCLUS. A critical distance of 3.0 between the classes was chosen in an attempt to develop the maximum number of signatures. In addition to locating the water storage ponds at Kremlin, it was hoped that a railroad signature and a housing-farmstead signature could be developed. The water reserviors were successfully mapped by three characters, but when the other nine signatures were mapped by DCLASS it was found that several were similar to previously classified areas and the remainder could not be related to any known object. Once the water ponds at Kremlin had been located, attention was directed to the Kenneth E. Wilson farm in the primary test site, for which accurate ground truth was available. DCLUS was run on a small area to determine a signature for farmsteads. The only useful signature in this output was one that appeared to map the trees around the house. When this signature was put into DCLASS it did, in fact, map the trees at two farmsteads as well as grass field boundaries.

The categories and signatures obtained at this stage are presented in Table 3 and discussed below. Portions of the maps of these categories is shown as Figures 5 and 6 .

SUMMER FALLOW. A signature was developed that is capable of mapping the majority of fields known to be in summer fallow. Four additional signatures were developed, each of which is capable of mapping portions of known summer fallow fields. At the present time it can only be speculated that observable ground differences such as soil type or moisture can be correlated to the various bare soil signatures. These additional bare soil categories show linear traces attributable to poor scan lines. After completing the mapping of the two test sites, an area was found that had not been classified by any of the other signatures. The pattern in the output was the size of adjacent 40-acre strips. The STATS program was used to determine a signature for these areas. This signature had the highest reflectance of any signatures previously developed. It was similar to a signature called LOW SPOT as it had been found in a low spot in the primary site. It was postulated that this signature (FIELD WEST OF LAKE) was, in fact, a smooth, bare crusted field such as occurs after a rain shower on rod-weeded summer fallow. The previous signature was then renamed CRUSTED, ROUGH as the field in the primary test had a furrowed, clod-like surface. The area mapped by these two signatures had not been worked since the last rain shower. SUMMER FALLOW is shown as -'s on Figures 5 and 6 . FIELD WEST OF LAKE is shown as |'s.

STUBBLE. This category required four signatures. It was not possible to find any one signature capable of completely mapping known stubble fields by themselves, although there was often a predominant signature in a field. Whether this signature is indicative of a particular crop type is unknown at this time. Another possible correlation is between signatures and yield, as measured by thickness of stand and weed growth, but this would be very difficult to prove at this time.

Table 3: Categories and Associated Spectral Signatures Used to Map Hill County, Montana

CATEGORY NAME	NUMBER	SYMBOL	LIMIT	SPECTRAL RESPONSE FOR CHANNEL 4	5	6	7
SUMMER FALLOW	1	-	5.0	31.77	32.59	31.52	14.49
SUMMER FALLOW	2	-	6.0	30.33	31.33	31.67	15.33
SUMMER FALLOW	3	-	6.0	30.71	31.82	30.98	14.35
SUMMER FALLOW	4	-	6.0	30.73	31.29	30.59	13.61
SUMMER FALLOW	5	-	6.0	33.50	34.50	32.00	16.00
STUBBLE	6	*	6.0	33.66	34.34	37.61	18.20
STUBBLE	7	*	6.0	37.68	41.79	41.22	19.14
STUBBLE	8	*	6.0	27.06	25.03	33.94	17.47
STUBBLE	9	*	6.0	34.31	36.38	42.81	19.13
VEGETATION	10	V	6.0	29.69	27.20	28.54	13.46
RANGE	11	R	6.0	23.50	22.50	33.00	17.00
PRAIRIE	12	P	6.0	26.67	25.00	25.67	13.00
MUD FLATS	13	1	6.0	39.66	37.69	21.12	3.50
MUDDY SHALLOW WATER	14	2	6.0	38.32	33.07	15.09	1.77
MUDDY WATER	15	3	6.0	34.51	24.50	9.98	1.23
CLEAR WATER	16	4	6.0	27.96	16.52	7.23	0.98
KREMLIN WATER	17	5	6.0	26.50	22.00	18.00	8.00
LAKE SHORE	18	6	6.0	30.87	23.12	17.00	5.50
CUT BANK	19	B	6.0	45.50	46.75	40.50	18.00
CRUSTED, ROUGH	20	C	6.0	40.94	46.00	43.50	19.94
FIELD WEST OF LAKE	21	1	6.0	43.71	48.62	49.57	23.14
CREEK	22	7	6.0	23.55	17.76	38.73	22.79

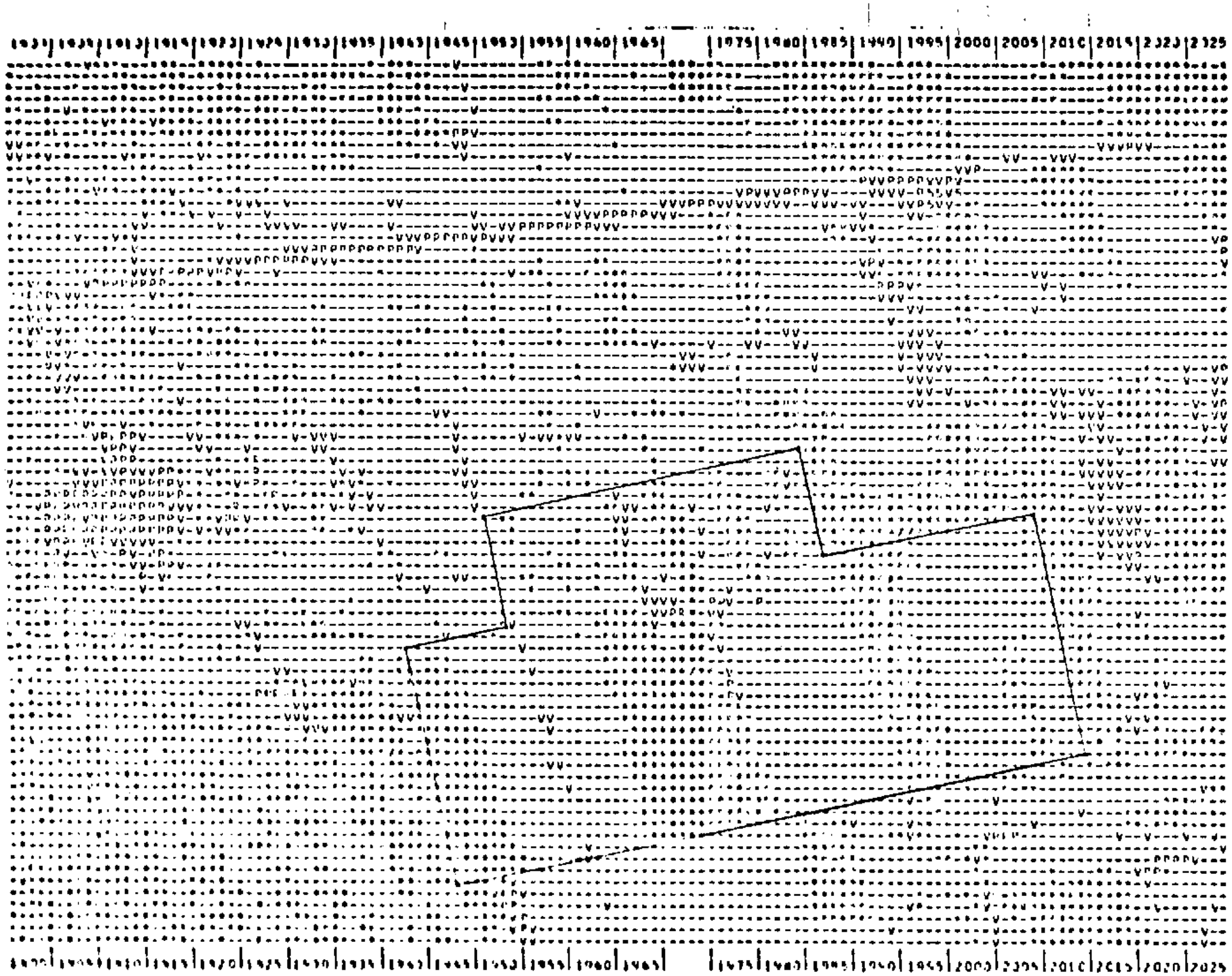

Figure 5 : Classification map of the primary test site. (Symbols are defined on Table 3.)

Figure 6 : Classification map of the secondary test site. (Symbols are defined on Table 3.)

In the primary test site, there is some improper classification of stubble as summer fallow. When lines are compared on single channel NMAP output for channels 4, 5, or 6, banding of data is evident. These bands are also seen on DCLASS output. STUBBLE is shown as *'s on the figures.

WATER. There are five signatures in the water category. Four of these map out the storage reservoir of Fresno Dam. The difference between these signatures can be attributed to increased sediment and shallower water encountered away from the dam area. The fifth signature, KREMLIN WATER, locates the water storage reservoirs at the community of Kremlin. These reservoirs cover an area 660 feet by 1320 feet, and contain water with a high percentage of suspended clay. The signatures are probably also influenced somewhat by the surrounding vegetation.

In a 72 square mile area lying predominantly east and south of the primary test site, there were a total of approximately 1500 acres classified as KREMLIN WATER. Parts of this area were checked against available ground truth and it was found that this was a valid calssification. With no reason to expect confusion with other categories, it should be safe to assume that there is sufficient water stored in farm ponds and surface depressions in this area to yield the water signature. This signature is mapped with 5's on both figures. The other water signatures are mapped with numerals 1 through 4 (although 3 and 4 do not appear on the restricted area of the figures shown here).

VEGETATION. A signature from a DCLUS run was found to map the grassy strips between summer fallow fields. The vegetated strip is less than 20 ft wide where this signature was developed. Areas of vegetation are also frequently found associated with these signatures. It appears also that a considerable amount of grazed, short grass, vegetation is being improperly classified as STUBBLE or SUMMER FALLOW around Fresno Dam on the DCLUS output. VEGETATION is mapped with V's in the figures.

RANGE and PRAIRIE. Areas of dense or ungrazed grassland are mapped with either the RANGE or the PRAIRIE signature. The PRAIRIE signature is predominant, and the RANGE signature is required to "fill in the blanks." PRAIRIE is mapped with P's on the figures; RANGE is mapped with R's.

CUT BANK. The level of Fresno Dam is approximately 150 ft below the surrounding land. Gullies carrying runoff water to the lake are often located with the CUT BANK signature, which maps eroded areas. Areas around these eroded spots are often mapped with the VEGETATION signature or the PRAIRIE signature, indicating moisture available for grass growth. The CUT BANK signature is mapped with B's.

CREEK. A CREEK signature, which was specific for the willow and brush areas along Big Sandy Creek and the Milk River, was also added. This signature is not shown on the figures, as the water courses are outside the portions of the maps displayed.

Results and Conclusions

A land use map of a three mile area in Hill County, Montana was successfully prepared. An additional 12 square mile area was also mapped with only one improper classification: an area of grazed, native short grass vegetation was mapped as STUBBLE and SUMMER FALLOW. The location of the Great Northern and Burlington Railroad could be seen as a linear trace of VEGETATION and PRAIRIE categories. U. S. Highway 2 could not be mapped. The location of farmsteads could often be inferred by small groupings of VEGETATION, PRAIRIE, and CUT BANK signatures. Loose, bare soil (SUMMER FALLOW) was differentiated from crusted bare soil. It was not possible to make valid separations within SUMMER FALLOW categories, possibly because of bad scan lines within the data. Six categories of Water were defined with their differences related to sediment content and depth.

To determine the validity of these categories over a larger area, 150 square miles were mapped. No obvious, improper classification resulted. The field patterns remained regular, alternating between SUMMER FALLOW and STUBBLE. The Milk River, flowing out of Fresno Dam was discernable, as was a creek flowing into the Milk River.

Analysis Cost Estimates

It is estimated that between 15 and 30 minutes of computer time was involved in this project. Total signature costs were approximately

$1000 ($600 for the computer, $400 for personnel). Utilizing these 22 signatures, it is estimated that $560 would be required to map an entire ERTS-1 frame (8,535,478 acres). At current computer rates charged at Penn State, this mapping would cost $0.000065 per acre. Spreading the $1000 signature development costs over the 6 to 8 ERTS frames that could be mapped in this area at this time of year, would result in a negligible increase in cost per acre.

Hidalgo County, Texas

The Texas test site lies north of the Rio Grande River in Hidalgo County. Most of the area is under canal irrigation, with well irrigation in the northern portion. Major crops include citrus fruits, vegetables, sugar cane, cotton, and sorghum. Large areas of unirrigated rough land have been left in native vegetation for pasture. Fields range from 20 to over 40 acres in size. The climate is semi-humid with over 30 inches of rain per year, most of which occurs in the winter and spring months. Irrigation is generally required for summer and fall crops. Most soils are developed from aeolian deposits of sand and silt. In the flood plain valley, the soils are composed of alluvial silts and clays. The topography is generally flat with an occasional gully cutting toward the river.

The area was flown in July of 1971 to obtain a 1:60,000 scale photomosaic. This mosaic is being used in conjunction with available maps and field-derived ground truth collected by the Weslaco Station of the Agricultural Research Service (ARS) (U. S. Department of Agriculture). This data is collected on an agricultural field basis, and consists of crop, stage of growth, and field condition.

Procedure

Initial contact was made with Dr. C. L. Wiegand of the ARS/USDA office in Weslaco in the fall of 1972. Approximately two weeks were spent in the area in December of that year, encompassing the time of the December 16 ERTS-1 overpass (scene 1146-16323). Arrangements were made at this time to receive copies of a portion of the ERTS support underflight data from C130 Flight 207, flown July 17, 1972. A 24-channel Bendix scanner was operated on this flight. A preprint of this scanner imagery has been received, along with computer compatible tape of data from eleven channels (see Table 4). The following ground truth data was collected by ARS personnel at the time of this underflight:

1. Field identification
2. Crop species
3. Percent crop cover
4. Percent weed cover
5. Crop maturity
6. Crop height
7. Crop condition
8. Soil condition

The Soil Conservation Service (SCS) has provided photocopies of soil mapping along the flight line. The ARS office is providing ground truth data for selected fields in the study area, collected on December 16, 1972, the date of the ERTS-1 overpass. They are also providing black-and-white and color copies of the 1:96,000 special aerial mosaic of

Table 4: Spectral Ranges for Eleven Channels of Data Collected on C130 Flight 207 Over Hidalgo County, Texas

Channel	Wavelength Range (in microns)
3	0.46 - 0.52
4	0.54 - 0.58
6	0.65 - 0.69
9	0.83 - 0.88
10	0.98 - 1.04
11	1.20 - 1.30
12	1.53 - 1.63
13	2.10 - 2.38
18	9.00 - 9.50
19	9.50 - 10.20
20	10.20 - 11.00

Hidalgo County -- photography flown in 1971, by Ames Research Center, for a ground truth base map for ERTS-1 studies. ERTS bulk digital tapes and imagery for the December scene (1146-16323) were ordered in January 1972. The tapes were received in mid-April, but the imagery has not yet arrived.

Preliminary Results and Conclusions

Analysis of data from this site has just begun. Brightness maps, generated by the NMAP program[1], clearly show the Rio Grande River. Several large fields, presumably of growing crops, can be seen on the Mexican side of the river. Vegetable cultivation on the U. S. side is shown by high reflectance in a regular field pattern. Citrus fruit cultivation is not evident from these first brightness maps. However, the change from irrigated to dry land is apparent, as is the difference between bare soils and native vegetation seen at this time of year (December).

Summary and Conclusions

Agricultural areas were selected for analysis in southeastern Pennsylvania, north central Montana and southern Texas. These three sites represent a broad range of soils, soil parent materials, climate, modes of agricultural operation, crops and field sizes. In each of these three sites, ERTS-1 digital data were processed to determine the feasibility of automatically mapping agricultural land use. In Pennsylvania, forest land, cultivated land, and water were separable within a 25,000 acre area. Four classes of water were also classified and identified, using ground truth.

A less complex land use pattern was then analyzed in Hill County, Montana. A land use map was prepared showing alternating patterns of summer fallow and stubble fields. The location of farmsteads could be

[1]For complete program descriptions, see ORSER-SSEL Technical Report 10-73.

inferred, along with that of a railroad line. A river and a creek flowing into the river were discernable. Six categories of water, related to sediment content and depth, were defined in the reservoir held by the Fresno dam. These classifications were completed on a 150 square mile area.

Analysis of the data from Texas is in its formative stages. A test site has been selected and a brightness map has been produced.

Continuing Investigation

During the 1973 growing season, thematic maps of the cropping pattern for each of the three test sites will be produced as data from good quality ERTS scenes become available. Soil and moisture conditions, vegetative cover and crop conditions will be determined. It is hoped that such information will assist the farm manager to plan for optimum use of his land.

The level of land use mapping will be refined beyond that attained to data. It is hoped that crop types, soil types, various assemblages of native vegetation, and several water categories will be delineated. An attempt will be made to map towns and individual farmsteads, as well as roads. With towns, farmsteads, and roads mapped, orientation within a scene will no longer present the major problem experienced early in this investigation.

The individual agricultural land use maps prepared for each of the test sites will be evaluated and compared as follows:

1. For each test site, land use maps prepared for different seasons will be compared, and seasonal data will be merged in those cases where a significant gain in map accuracy will result. The most desirable season, or seasons, for agricultural land use mapping in each area will be determined.

2. The optimum mapping methods determined for each site will be compared, to answer the question: Is there a single method which can be applied to all three sites, or must modifications of a single method or entirely different methods be applied to different types of agricultural areas?

3. The utilitarian value of ERTS-1 data will be evaluated with respect to its usefulness as a major input into land management plans.

4. The performance of the ERTS-1 data collection systems will be evaluated with a view toward suggesting modifications for future data collection platforms.

ORSER-SSEL Technical Report 25-73
The Pennsylvania State University
May 1973